Wideband Feeds and Low Noise Amplifiers for Large Arrays

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Abstract

The state of the art for feeds and LNAs with frequency ranges approaching one decade will be presented. These components reduce the cost of receivers required to cover a given frequency range and enable observations requiring large bandwidth such as spectral index measurements, search for spectral lines with unknown red shift, and detection of transient events. An example of a 2 to 12 GHz feed will be given and compared in efficiency with an octave band feed. Low noise amplifiers for the 0.5 to 12 GHz range utilizing HEMT and SiGe bipolar transistor will be described.

1. Wideband Feeds

Most current radio astronomy receivers have octave or less bandwidth. During the past several years several groups have designed and tested feeds with bandwidths approaching a decade [1, 2, 3, 4,]. Slides describing these feeds will be shown at the assembly. The wideband feed currently under development at Caltech is the quad-ridge flared horn, QRFH, design [5] shown in the figure below.

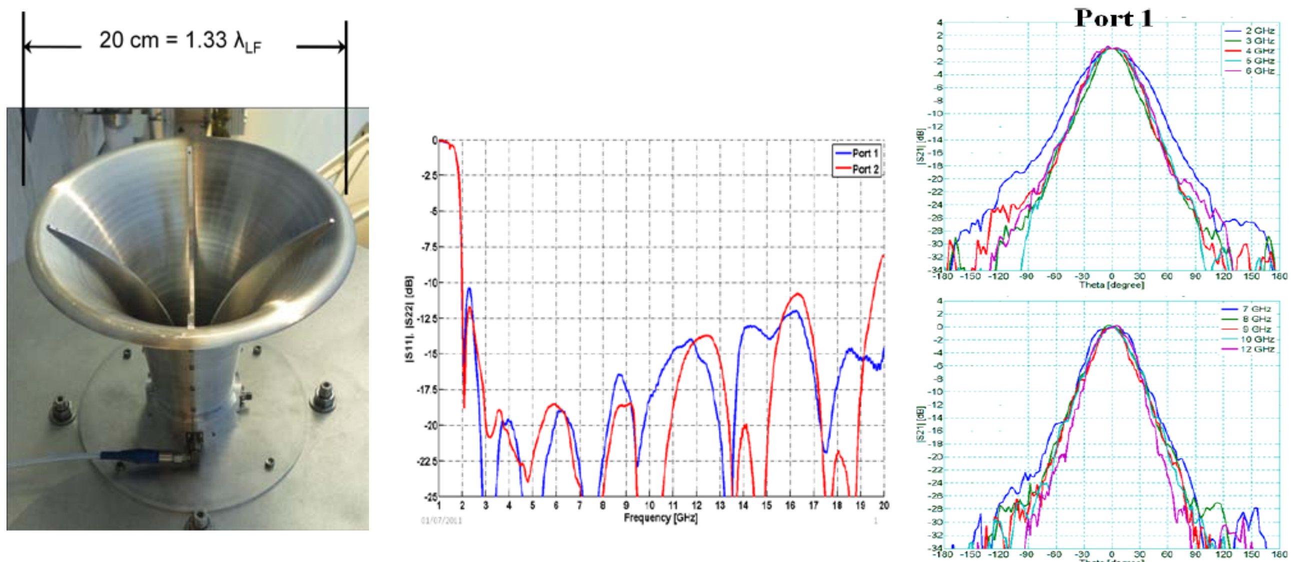

Figure 1 - QRFH feed photograph, return loss from 1 to 20 GHz, and 45 degree patterns, 2-12 GHz.

The QRFH feed has 50 ohm single-ended output and can have 10 dB beamwidth variable from 35 to 65 degrees by changing the shape parameters of the feed. The feed shown in Figure 1 can be scaled to any 1:6 frequency range for reflectors with a 45^{O} edge angle; a feed for a 1:4.5 frequency range for 65^{O} edge angle has also been designed.

2. Low Noise Amplifiers

Cryogenically-cooled indium-phosphide, high-electron-mobility-transistor (HEMT) are used almost exclusively in radio astronomy arrays from 0.5 to 115 GHz. A widely-used LNA in wideband systems is the WBA13 monolithic 3-stage amplifier designed at Caltech and fabricated in the Northrop Grumman foundry in Redondo Beach, CA. This chip and the measured performance are shown in Figure 2.

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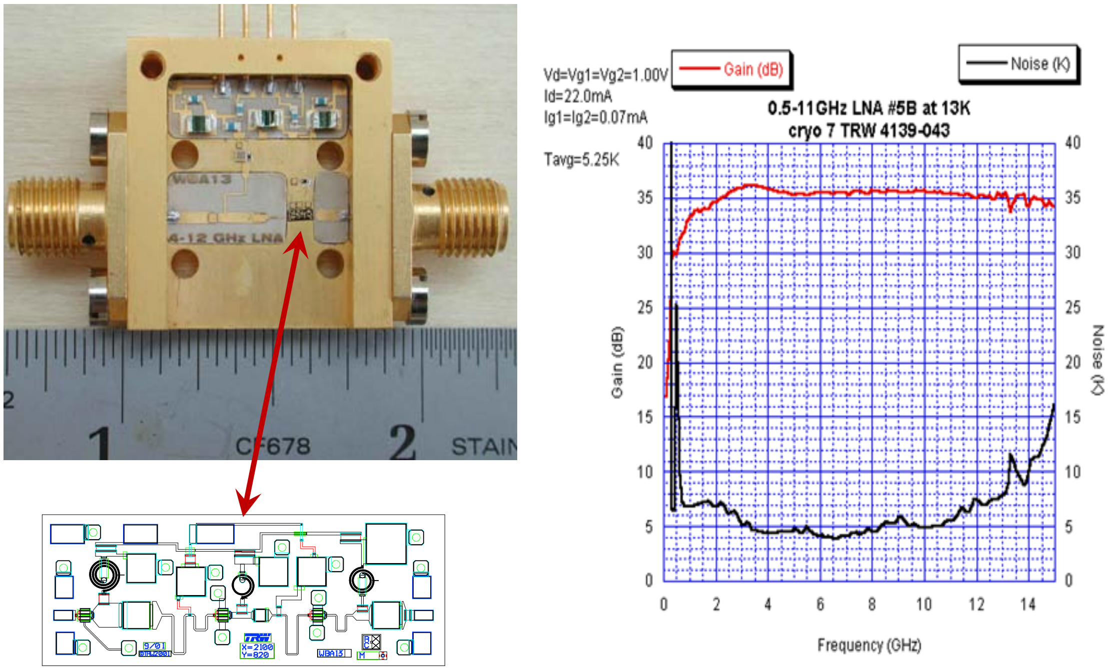

Figure 2 - InP HEMT 3-stage amplifer chip, 2mm wide, is bonded into the coaxial chassis shown at upper left to produce ~5K noise and 35dB gain at 13K from 1 to 12 GHz shown at right.

The InP HEMT results shown in Figure 2 are good but the cooled noise results vary by as much as 2:1 from chip to chip. This variation is costly when large numbers of LNA's are required for large arrays. During the past few years an alternative with similar noise and much better uniformity has been developed at Caltech by utilization of silicon-germanium , (SiGe) bipolar transistors. These devices are in rapid development for use in high speed communication and now have cutoff frequencies in the 300 GHz range. Ordinary silicon bipolar transistors do not work at cryogenic temperatures but SiGe devices greatly improve in performance with current gains as high as 20,000. An amplifier using commercially available NXP transistors has been repeatedly constructed with ~6K noise from 0.5 to 4 GHz [6]. Several manufactures of SiGe devices were evaluated for cryogenic noise in the Ph.D. thesis of J. Bardin [7] and the transistors of ST Microelectronics were found to have the best performance. A wafer segment shown in Figure 3 of ST low noise transistors and integrated circuit LNA's has been processed and results will be reported at the assembly.

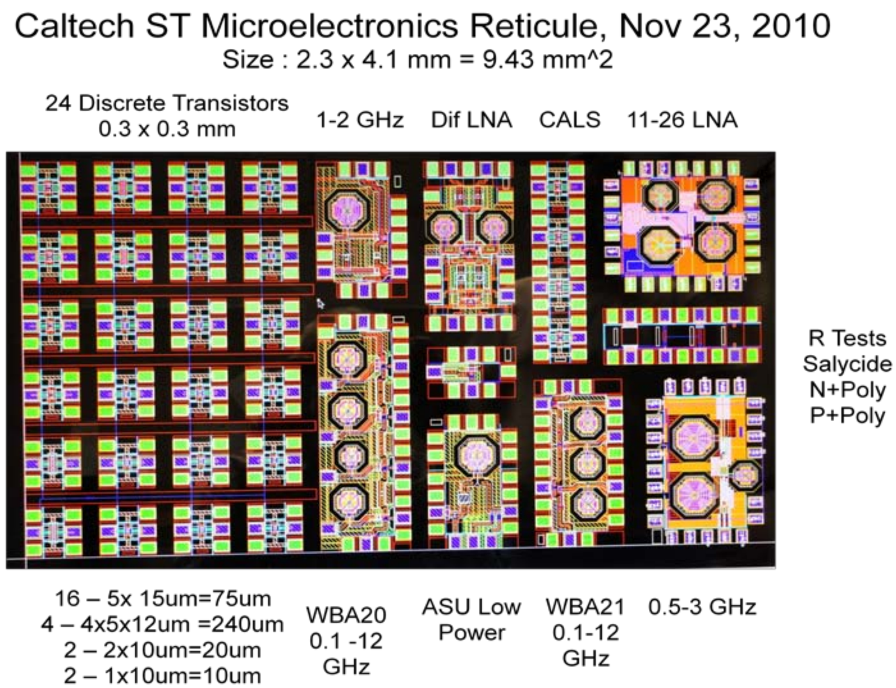

Figure 3 - Wafer segment of 24 discrete transistors, 7 MMIC LNA's, and calibration structure fabricated at ST Microelectronics and under test at Caltech.

3. References

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